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2018 Science of Signatures Capability Review



Chemical signatures from Mars and beyond: Science and engineering in extreme environments

Nina Lanza

24 April 2018

Space/Planetary Science

Extraterrestrial planetary environments are extreme

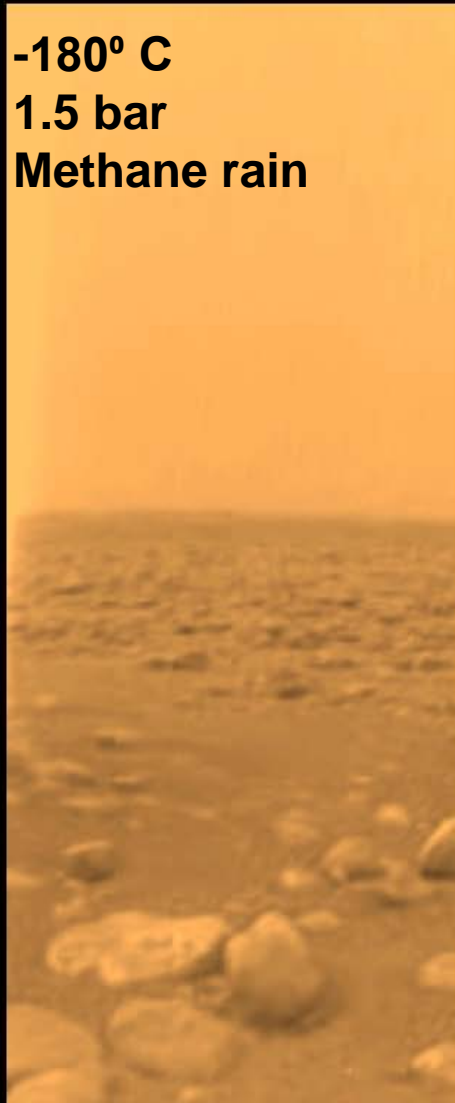
Venus

450° C
90 bar
Sulfuric acid rain



Titan

-180° C
1.5 bar
Methane rain



Mars

-55° C
0.006 bar
Dust storms



Moon

-180-115° C
0 bar
Abrasive regolith



Extraterrestrial planetary environments are extreme

Venus

450° C
90 bar
Sulfuric acid rain

Titan

-180° C
1.5 bar
Methane rain

Mars

-55° C
0.006 bar
CO₂ frost

Moon

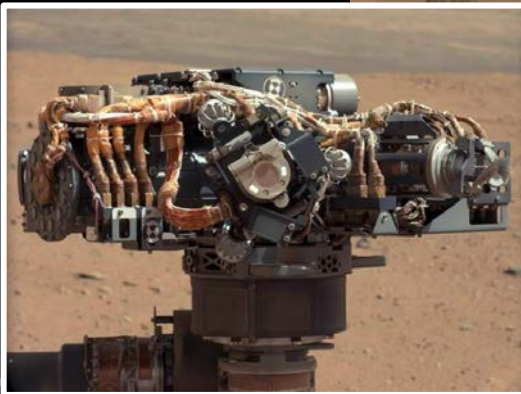
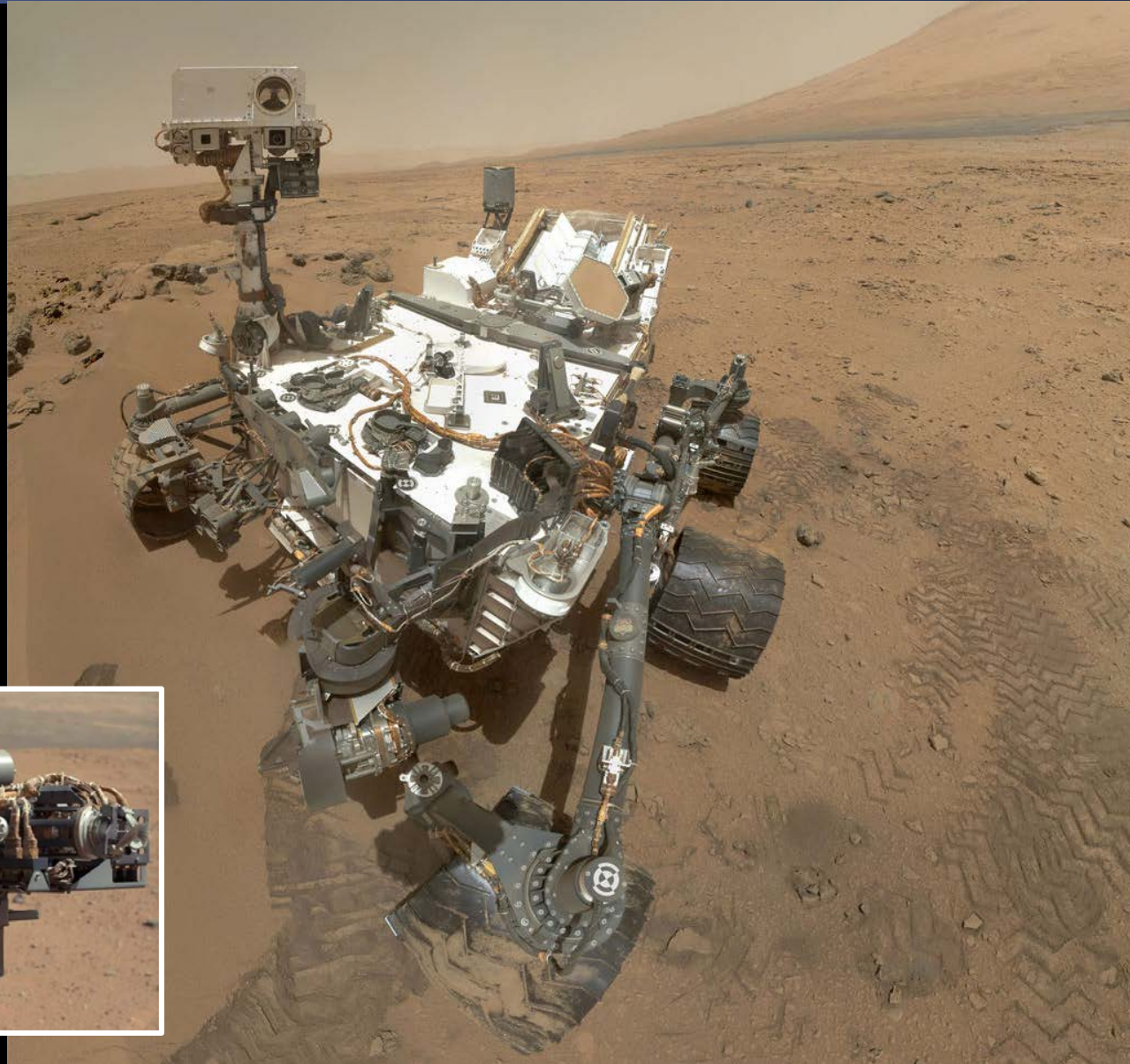
-180-115° C
0 bar
Abrasive regolith

Operating instruments in these environments is challenging!

- Extremes of temperature, pressure, radiation
- Remote operations
 - No fixes post-launch
 - Remote diagnostics of issues
 - Limited mass, data bandwidth
- Demonstration of Los Alamos capabilities
 - Robust, low mass hardware
 - Interpretation of remote, complex data
 - Many potential applications on Earth

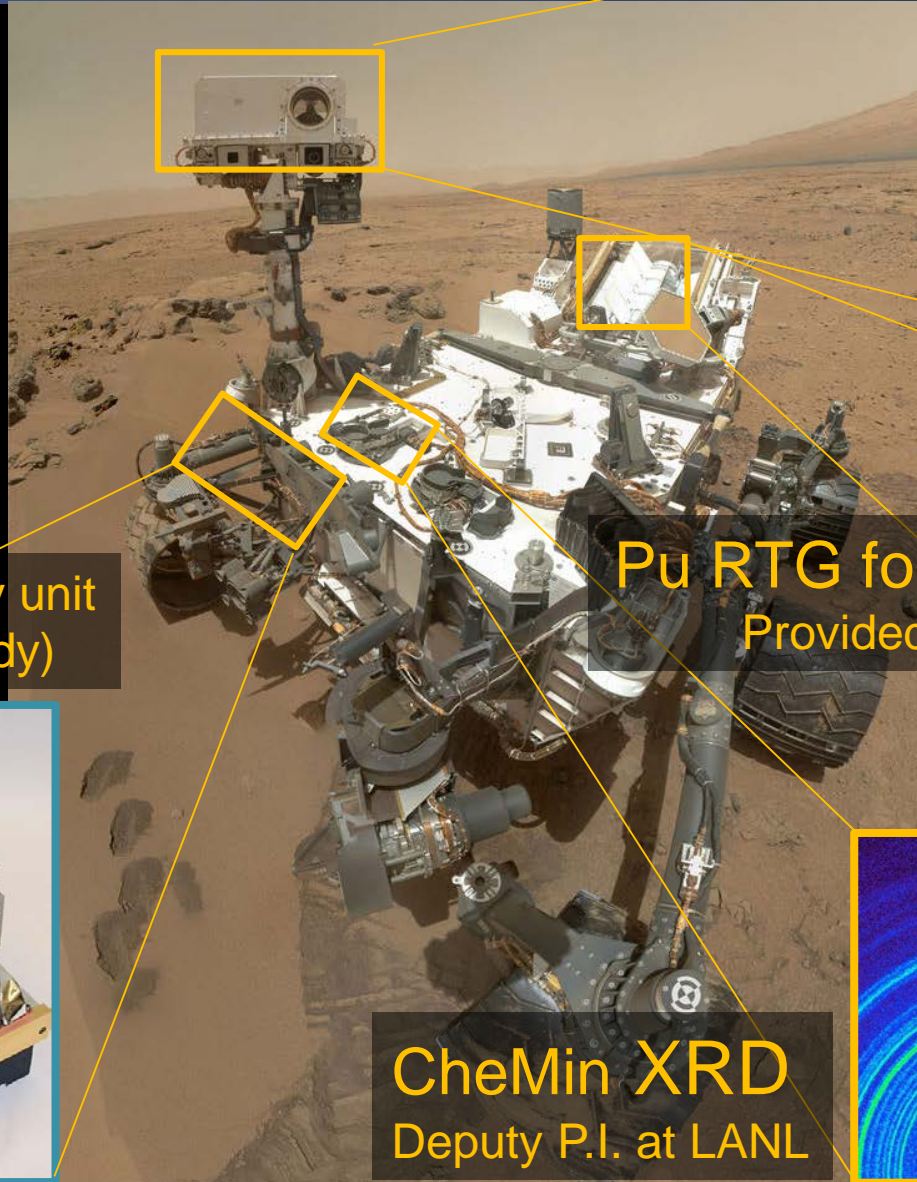
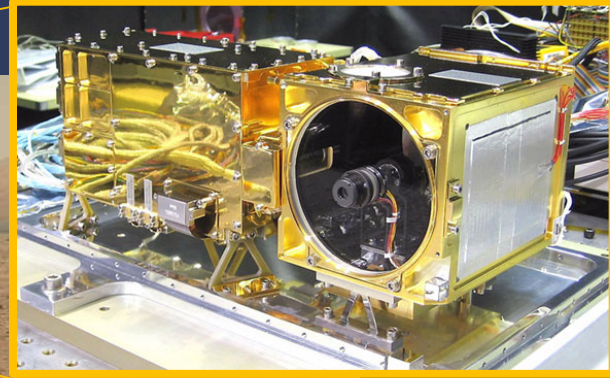


Los Alamos has instruments onboard the NASA Curiosity rover on Mars (selfie)



Los Alamos involvement with Curiosity

ChemCam (mast unit)
P.I. Roger Wiens, ISR-2



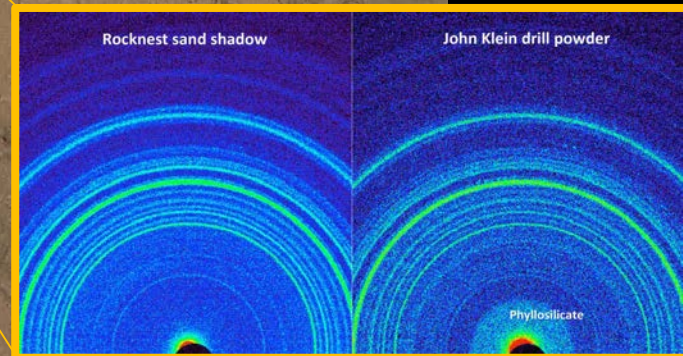
ChemCam body unit
(inside rover body)



Pu RTG for power
Provided by LANL



CheMin XRD
Deputy P.I. at LANL

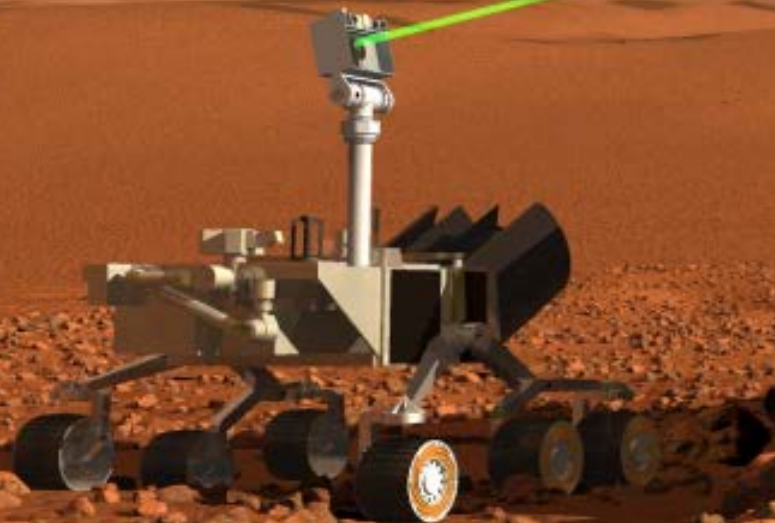


What is ChemCam?

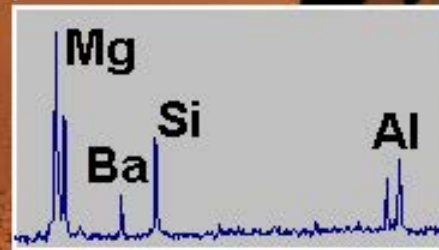


What is ChemCam?

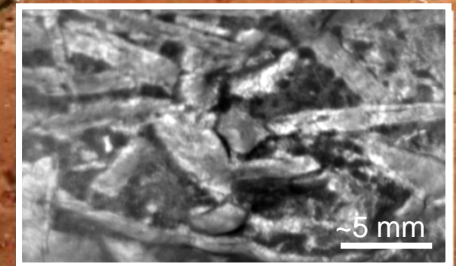
- **Two instruments**
 - Laser-induced breakdown spectroscopy (LIBS) → **remote chemistry** (1.6-7 m standoff)
 - Remote microimager (RMI) → **context image**
- **Small spot size (350-500 μm)**
- **Rapid analysis time**
- **Can detect all elements**



Intensity

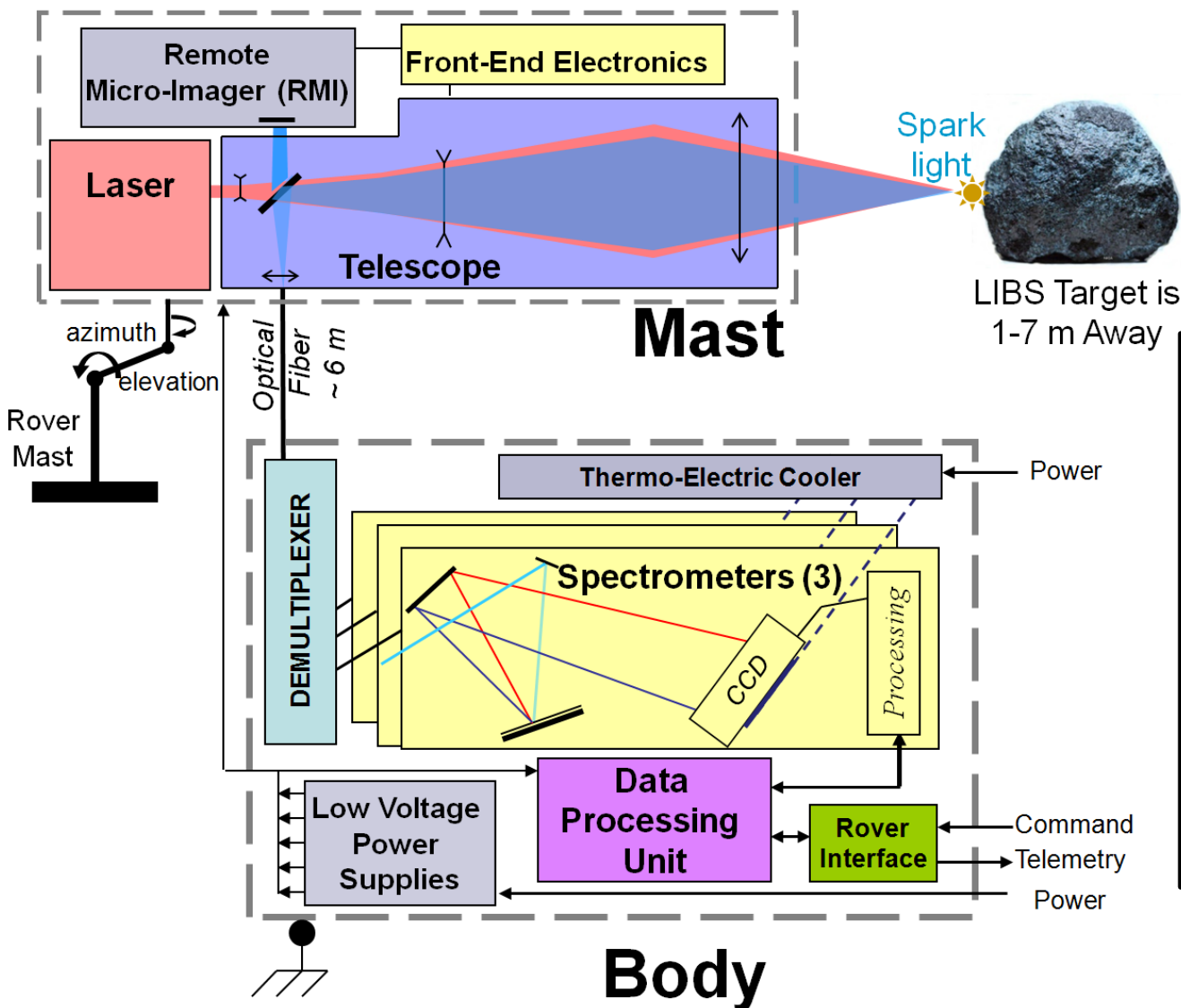


Wavelength



Harrison, sol 514

A detailed look at ChemCam



ChemCam by the numbers

Laser: Nd:KGW

Laser energy: 14 mJ on target

Laser wavelength: 1067 nm

Expected laser shots: 1 million

Laser shots so far: ~500,000

Spectrometer λ : 240-850 nm

Spectral resolution: 0.2-0.65 nm

RMI field of view: 20 mrad

RMI resolution: 0.05 mrad

ChemCam is a collaboration with CNES (France)

■ In-kind contribution (~\$30M)

- No NASA funding to France
- France built ChemCam mast unit (laser)
 - Shares operations 50%
- VERY rare relationship → uncommon for NASA

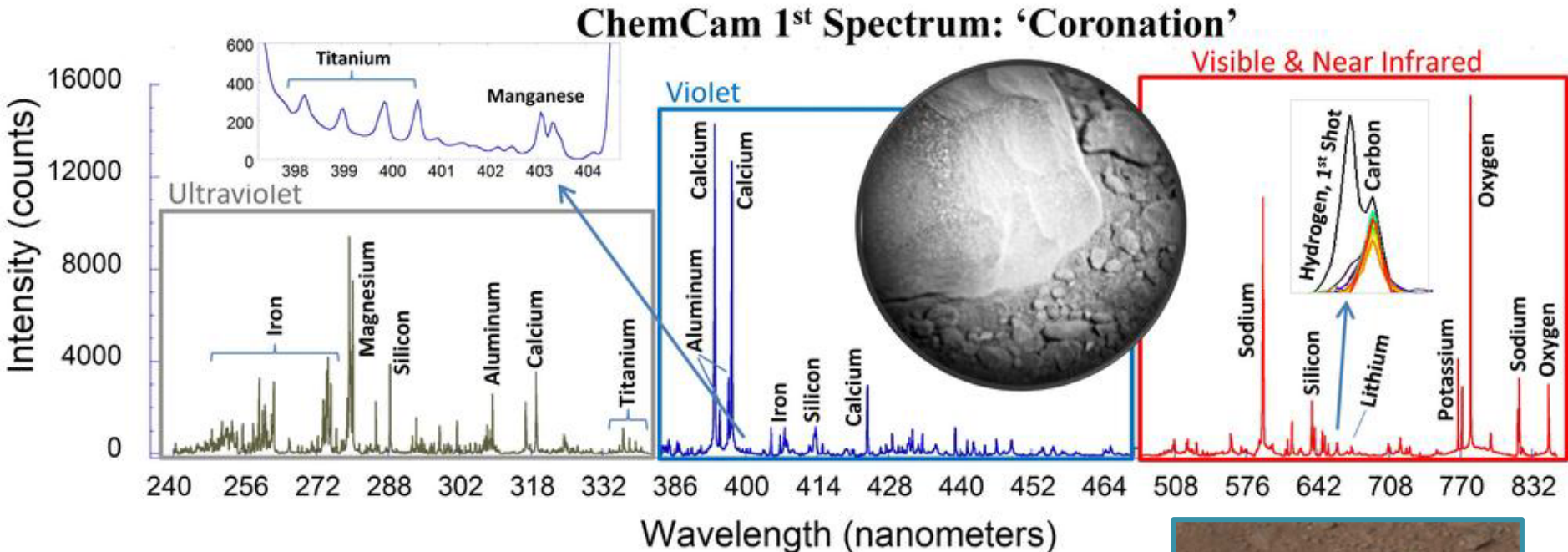
■ Additional institutional collaborators

- Jet Propulsion Laboratory
- U.S. Geological Survey
- California Institute of Tech.
- University of New Mexico
- Johns Hopkins APL
- University of Massachusetts
- Northern Arizona Univ.
- Institut de Recherche en Astrophysique et Planetologie (IRAP)
- Université de Nancy
- Université de Nantes
- ISTERRE Grenoble
- University of Leicester (UK)

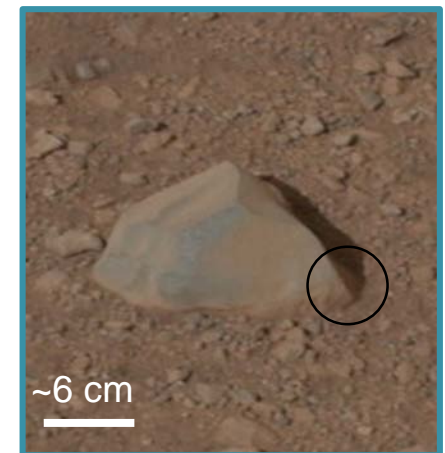
ChemCam is a large, international team!

UNCLASSIFIED

Data from the first ChemCam target on Mars (sol 14)



- A beautiful spectrum!
- Contains hydrogen in first shot
- Major discovery: Mars dust is hydrated
 - Meslin et al. (2013) in Science



ChemCam discovered high concentrations of manganese



Hydrothermal systems

Deep sea nodules

Rock varnish

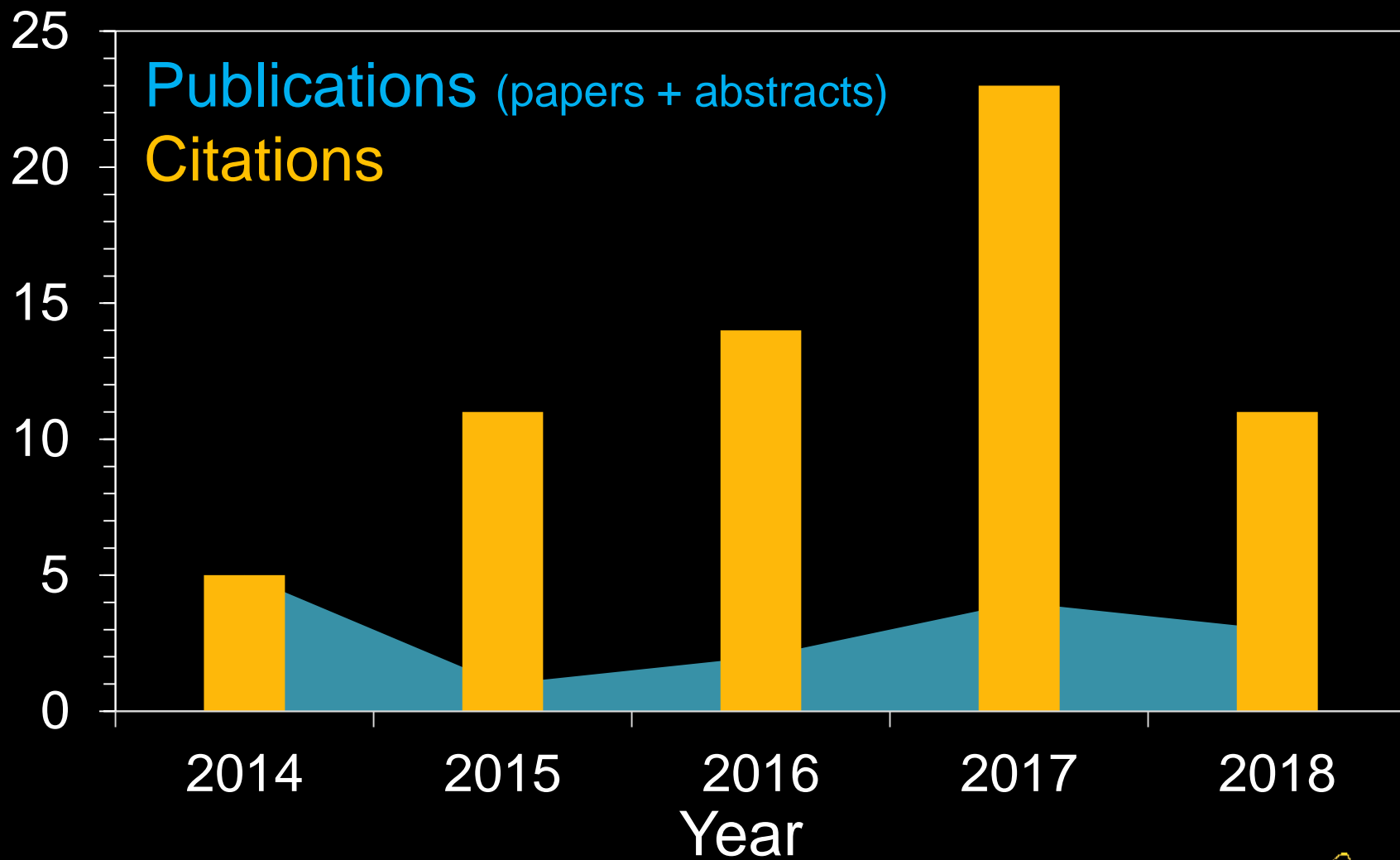
Dendrites/
fracture fills

- **To concentrate Mn requires**
 - Liquid water
 - Strongly oxidizing conditions (high pH, Eh)
- **Associated with biological activity (Earth)**
 - Mn deposits on Earth only observed post-photosynthesis → O₂

Presence of high Mn minerals indicates oxygenated atmosphere?

Lanza et al. 2014, 2016 Geophysical Research Letters

The ChemCam Mn discovery has opened a new field



ChemCam observed boron on Mars for the first time

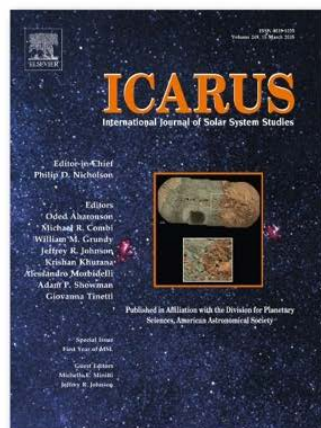
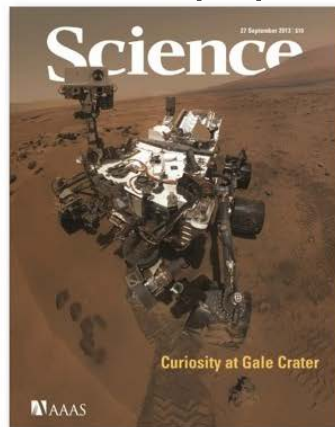
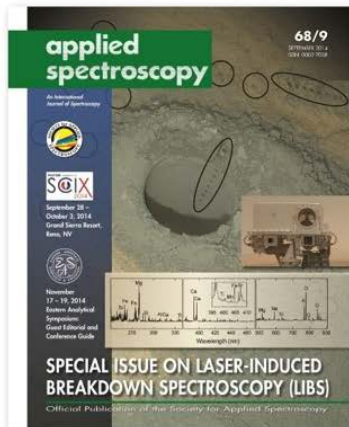


- First ever in-situ detection on Mars
- Found in light-toned veins
- Mid-level pH waters
- Potential role in early life formation (Earth)

Boron points to water conditions & is involved in prebiotic chemistry
Gasda et al. 2017, Geophysical Research Letters

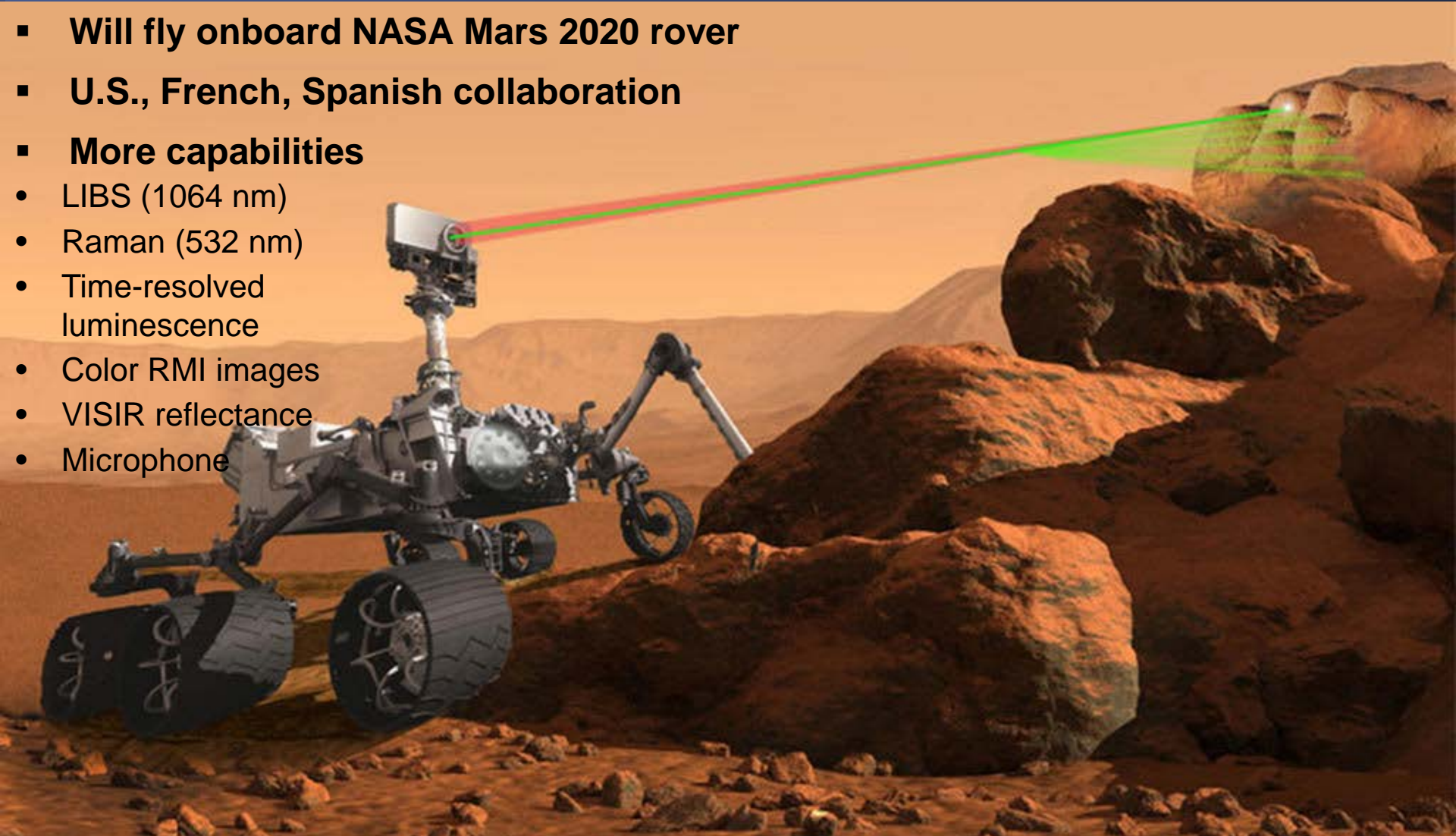
Los Alamos authors are publishing extensively on ChemCam

- 60+ ChemCam papers to date
 - ALL with Los Alamos lead or co-authors
 - 9 journal covers for ChemCam papers



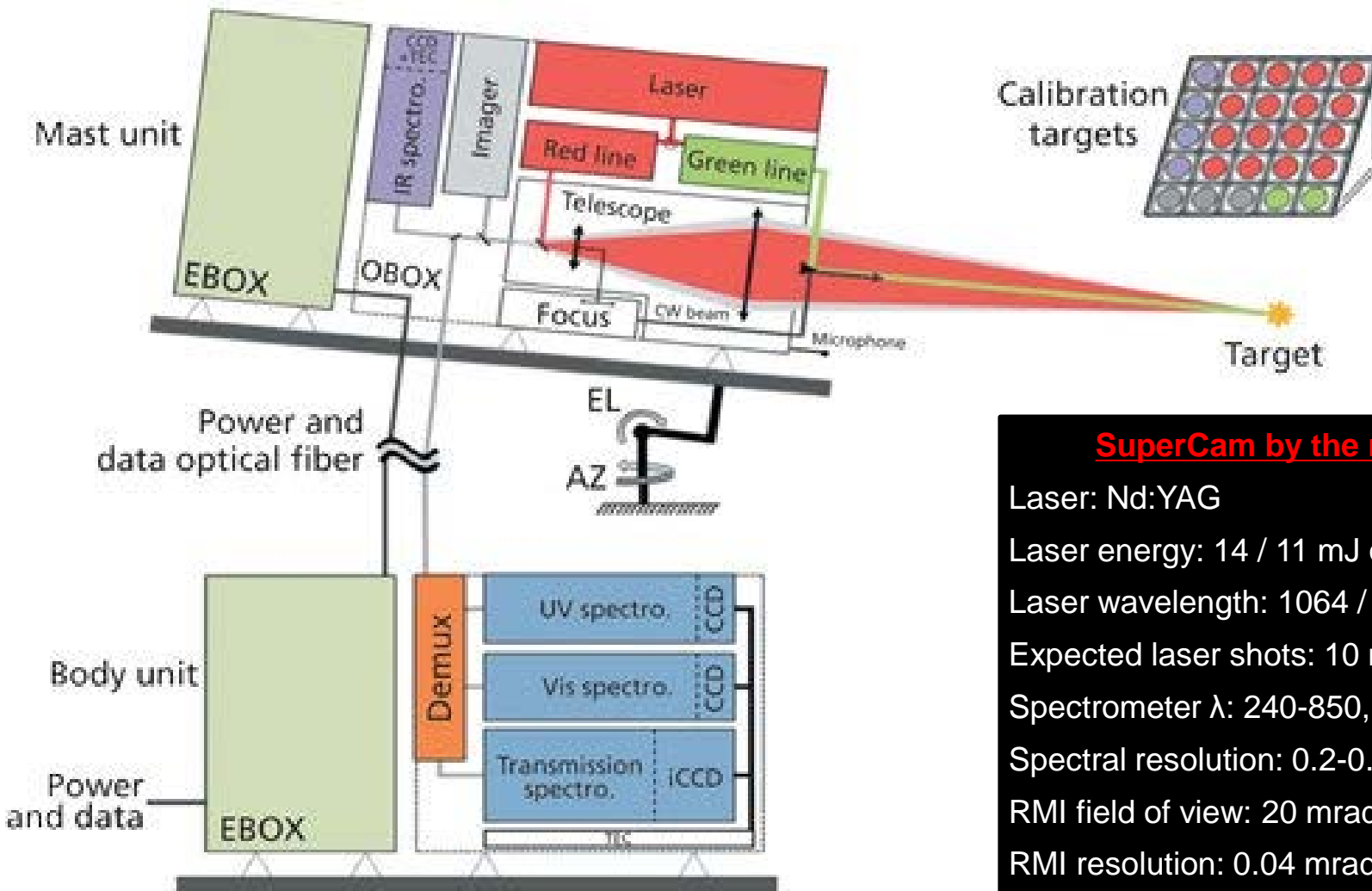
Los Alamos is currently building a next-gen Mars instrument: **SuperCam**

- Will fly onboard NASA Mars 2020 rover
- U.S., French, Spanish collaboration
- **More capabilities**
 - LIBS (1064 nm)
 - Raman (532 nm)
 - Time-resolved luminescence
 - Color RMI images
 - VISIR reflectance
 - Microphone



Many capabilities in a single instrument!

A detailed look at SuperCam



SuperCam by the numbers

Laser: Nd:YAG

Laser energy: 14 / 11 mJ on target

Laser wavelength: 1064 / 532 nm

Expected laser shots: 10 million

Spectrometer λ : 240-850, 1300-2600 nm

Spectral resolution: 0.2-0.4 nm / 30 cm^{-1}

RMI field of view: 20 mrad

RMI resolution: 0.04 mrad

Mic spectral range: 0.1 – 10 kHz

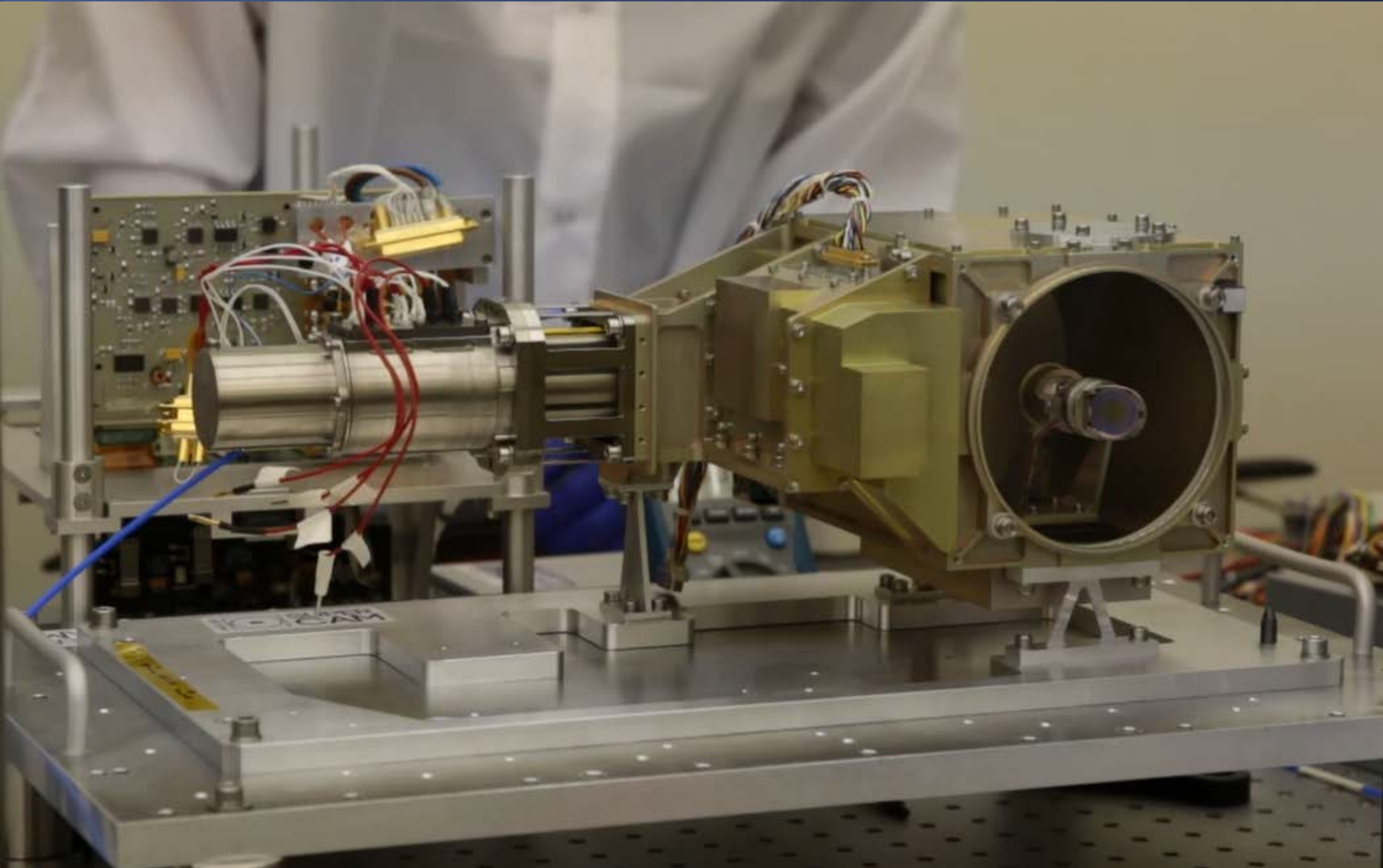
Why is combined LIBS-Raman “super”?

- What do geologists need to identify materials?
 - Rocks = specific mineral assemblages
 - Minerals = **chemistry (LIBS)** + **structure (Raman)**



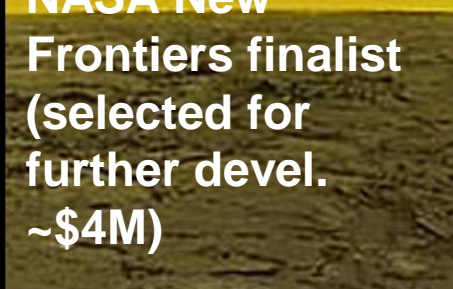



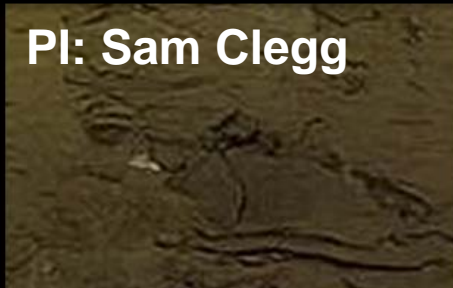



SuperCam can obtain both chemistry and mineralogy

SuperCam construction and testing has begun

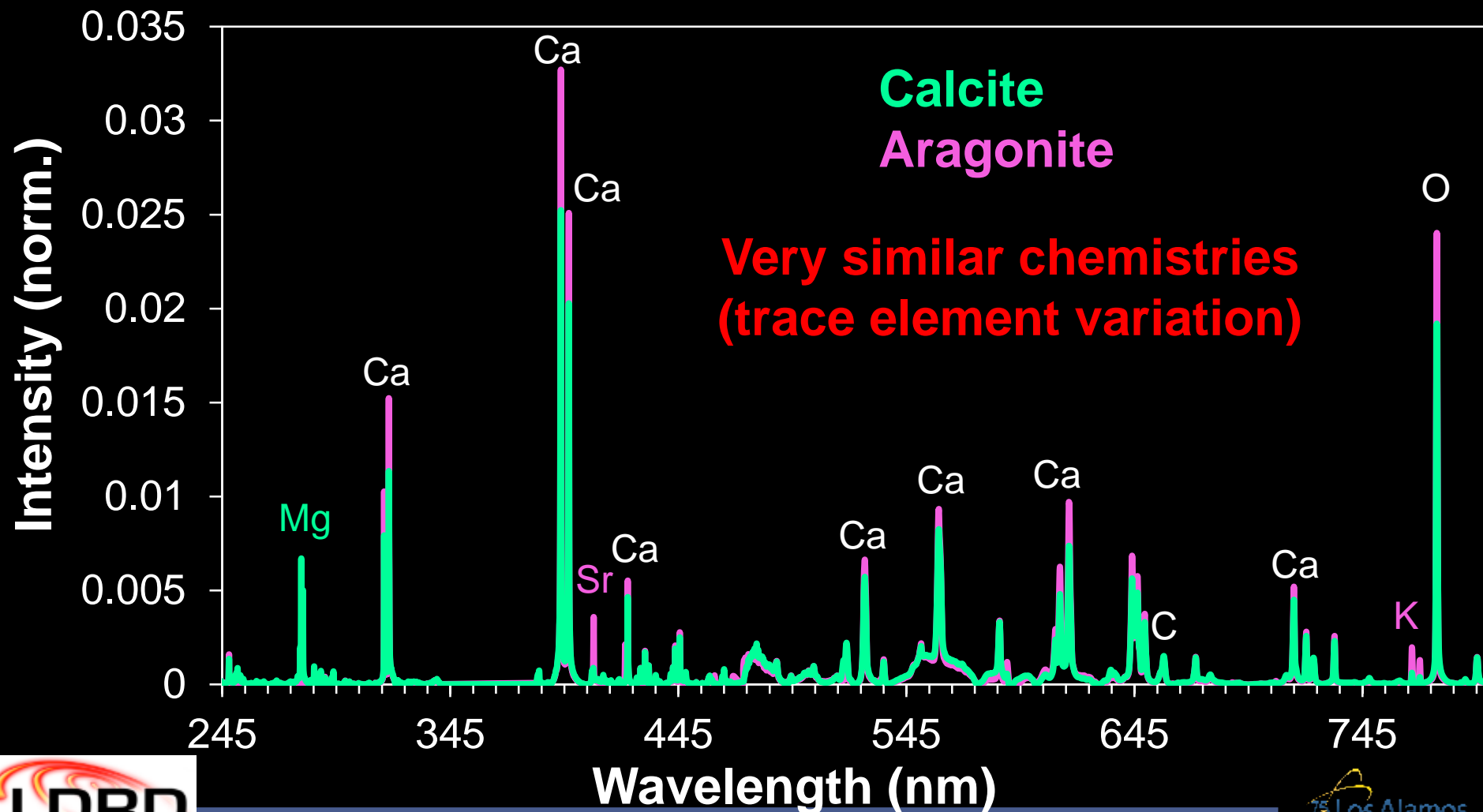


Los Alamos is developing additional extraterrestrial LIBS and Raman instruments

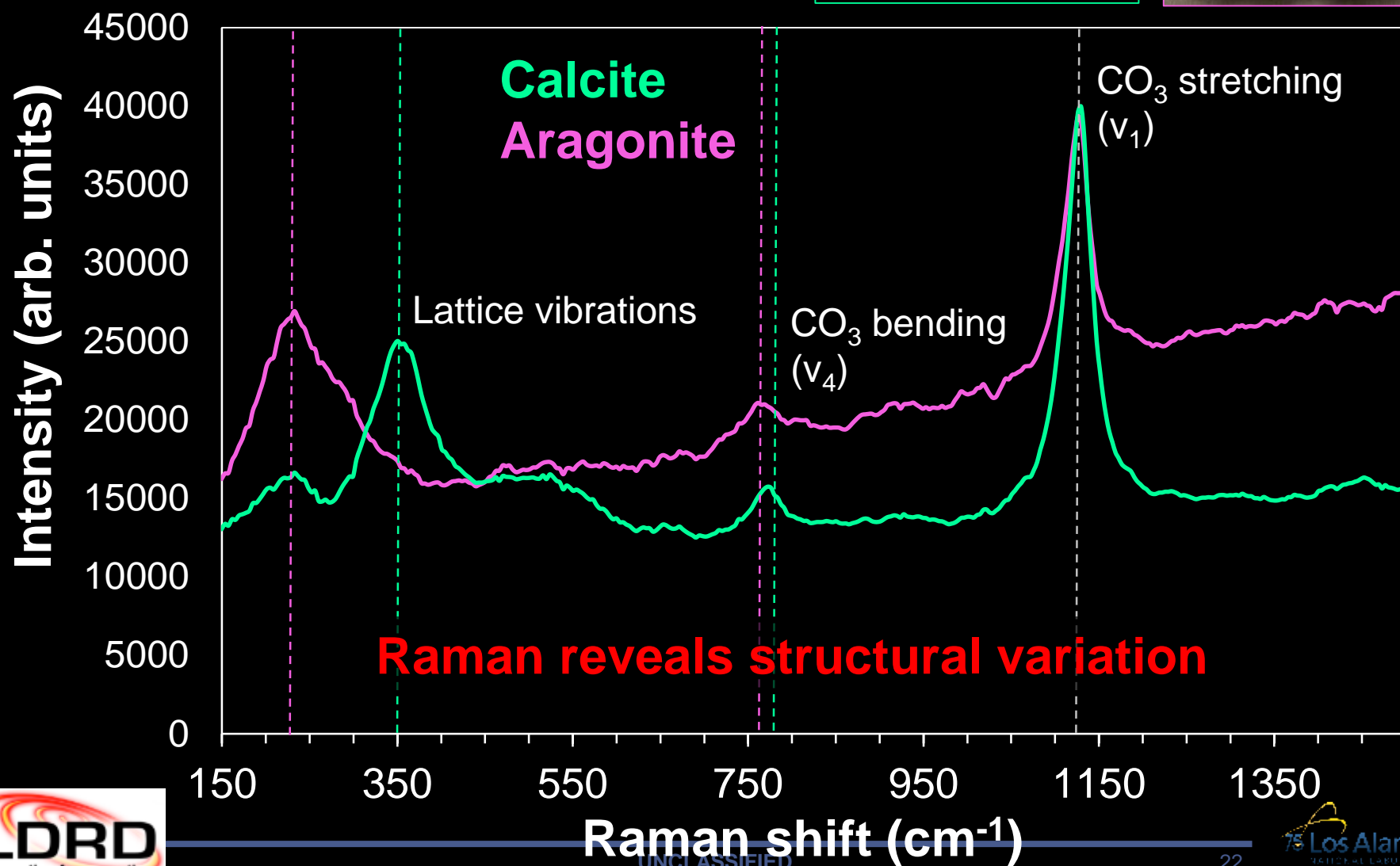
Mars	Mars	Venus	Europa
<u>SuperCam</u> LIBS-Raman, TR luminescence, reflectance VISIR, microphone	<u>SHERLOC</u> UV Raman + luminescence	<u>VEMCam</u> Raman-LIBS	<u>OrganiCam</u> Laser-induced fluorescence + imaging
Mars 2020 mission	Mars 2020 mission	VICI mission	Future NASA lander mission TBD
		NASA New Frontiers finalist (selected for further devel. ~\$4M) 	LDRD-ER (MID) 
PI: Roger Wiens	Co-Is: Roger Wiens, Sam Clegg, Tony Nelson	PI: Sam Clegg	PI: Roger Wiens
			

Backup

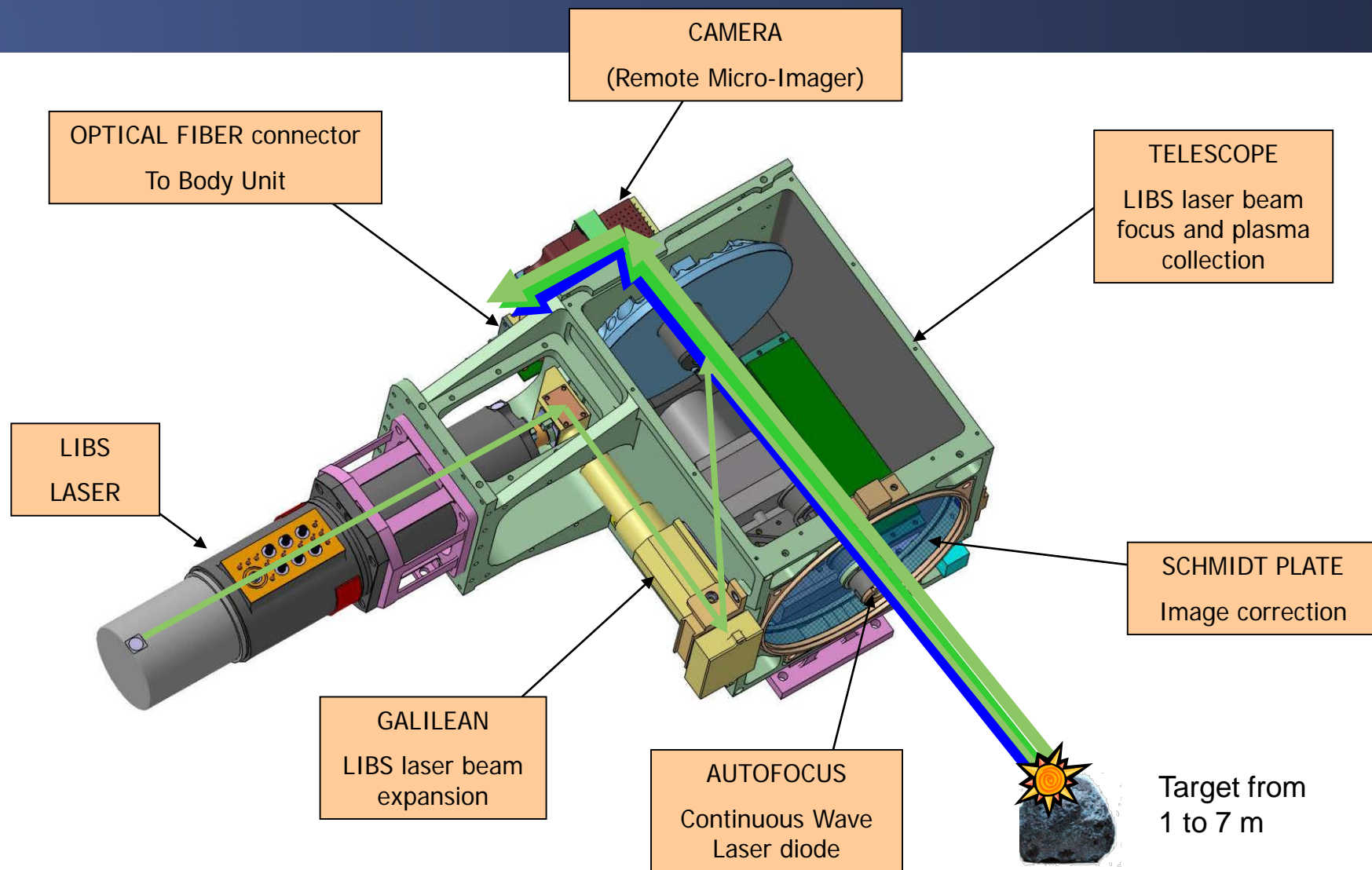
SuperCam LIBS provides chemistry



SuperCam Raman provides mineralogy



ChemCam mast unit optical box



ChemCam body unit optics

